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ABSTRACT

This study examines executive function and its relationship to attention dysfunction and working memory. It attempts to document the manifestations of executive function problems in school-related extended processing tasks, such as verbal problem-solving in math and reading of extended passages. Subjects (in grades 1-12) included 49 children with attention deficit disorder (ADD) not receiving medication, 38 ADD children receiving medication, and 50 non-ADD learning-disabled (LD) children. Factor analysis and regression analyses indicated that the underlying processing dynamic was different for each group. In the unmedicated ADD group, extended processing was found to be the primary factor (accounting for even more variance than working memory measures); in the LD group, a psychological proficiency factor was the dominant characteristic; and for the medicated ADD group, the medication appeared to alleviate the dominance of extended processing difficulties. Other findings suggested a phonologically driven correlate of extended processing in the LD subjects in comparison to an attention driven correlate in the ADD groups. Evidence for the possibility of at least two LD sub-types (attention-based LD and language-based LD) was found. Also noted is the impact of late developing frontal lobe neural pathways on the attention-working memory-executive function complex and the development of increasing learning difficulties through adolescence in the ADD population. Includes 54 references. (Author/DB)

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ADD, LD AND EXTENDED INFORMATION PROCESSING

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ABSTRACT

This study examines executive function and its relationship to attention dysfunction and working memory and attempts to document the manifestations of executive function problems in school-related extended processing tasks: verbal problem-solving in math, and reading of extended passages.

Three groups of subjects were selected to determine the relative effects of attention dysfunction on extended processing:

Attention Deficit Disorder (ADD), no medication (n = 49);
ADD, taking medication (n = 38); and
nonADD learning disabled (LD) (n = 50).

Factor analysis and regression analyses indicate that the underlying processing dynamic is different for each group.

Extended processing is the primary factor accounting for more variance than even rather pure working memory measures in the unmedicated ADD group.

The LD group is characterized by the dominance of a phonological proficiency factor.

Regression analyses confirm the difference in cognitive structures between LD and ADD groups and suggest a phonologically driven correlate of extended processing in the LDs in comparison to an attention driven correlate in the ADD groups.

These differences exist despite only minor differences in mean scores across groups.

Implications are drawn for diagnosis and treatment with particular attention to the effects on cognitive functioning.

Evidence for the possibility of at least two LD sub-types is presented and discussed: Attention Based LD and Language Based LD

The impact of late developing frontal lobe neural pathways on the attention - working memory - executive function complex and the development of increasing learning difficulties through adolescence in the ADD population is discussed. This has implications for appearance and/or worsening of dysfunction past age seven (the DSM III-R cut-off age for symptom manifestation).

Medication treatment seems to alleviate the dominance of extended processing difficulties and to have the effect of reorganizing the factor structure into more traditional processes determining academic performance.

FRAMEWORK

The effects of attention deficit disorder (ADD) have been found to be pervasive and to have their basis in a number of cortical, mid-brain, brainstream, and cerebellar areas and in the interaction of multiple neural networks and neuro-transmitter systems.

ADDs impact a wide range of cognitive functions. They are associated with many comorbidities including learning disability, language, and communication disorders, emotional, personality and behavior disorders.

This phenomenon has led
us to define ADD's
as follows:

DEFINITION OF ADD

Attention Deficit Disorders are neurobiologically-based disabilities which have pervasive, variable, and potentially life-long effects. Areas of human functioning implicated are: self-regulation, cognition, learning, communication, language, motivation, organization, neuromotor integration, coordination, judgment, rule-governed and reward-response behavior, self-worth, school, work and interpersonal performance.

Effects of this disorder are situation-dependent and reflect difficulty with the maintenance of consistency over time. Not all individuals have the same problems, to the same degrees, or at all.

Attention Deficit Disorders are, first and foremost, characterized by attentional processes which are inadequate for coping with the demands of development, and for successful age-, and context, and abilities - appropriate functioning. Coming to, staying at, and changing focus of attention to internal and external stimuli are all affected to different degrees in different individuals, in different contexts at different times.

Thus, attention deficit disorders are problems of learning and living. They are often, but not always, coexistent with motor hyperactivity, impulsivity, hypoactivity, passivity, social withdrawal, and comorbid disabilities in language, learning, affective regulation, personal and social functioning and communication.

THESIS

The role of attention reaches far into the cognitive system and will affect complex and extended information processing to the extent that

ADD COMPRISES AN ATTENTION BASED LEARNING DISABILITY.

The basis of attentional LD is embedded in the attention-working memory-executive function complex.

Due to late-acquisition of executive function processes related to neuro-development of the frontal lobes this disability may not be fully appreciated until later childhood and/or adolescence.

All cognitive processes influence each other and the attentional network appears to be the thread which provides cohesion to the quilt of cognitive (and other mind) processes.

The limitations in capacity which provide a challenge for extended information processing are based in the attention- working memory-executive function complex.

Working memory is a limited capacity holding tank which is composed of two functions:
Short Term Memory and Executive Function.
Finite capacity needs to be distributed between these two activities.

There is a need for executive function whenever there is an extended amount of information which must be considered and then managed. Extended information processing (of an academic, personal, or social nature) becomes an issue at all only because it, like all other cognitive mechanisms, is subject to the limited capacity system of which attention is a crucial part.

ATTENTION: "OUT THERE" AND "IN HERE"

The challenge for attention within these systems is to assist in highlighting relevant aspects of the task "out there".

But

attention must also be divided and deployed "in here" among (at least) the short term memory and executive components of working memory.

This would be a **slight** problem if both short term memory and executive function were encapsulated, isolated processes and the demands on attention were a simple issue of dividing attentional capacity neatly between the two. This is, however, clearly not the case. We know working memory to be embedded, at least partially, in the linguistic module which implicates the following processes: executive function, phonological processing, rapid automatic naming, the coordination among them and the other systems in which each of these are embedded.

Demands on attention, then, increase exponentially.

EXECUTIVE FUNCTION: A LATE BLOOMER

The executive function component has its neurological basis in the frontal lobes and its multiple, reciprocal connections throughout the human brain.

Frontal areas and therefore executive function have been identified as late developing in terms of myelination. Executive function is associated with mature judgment, controlled thinking and behavior as well as the conscious directing, planning, and monitoring of behavior.

Thus, cognitive impairment associated with executive function would be expected to manifest later in development. This would be true academically, and in terms of personal and interpersonal and social emotional/behavioral functioning.

In school, executive function problems are likely to manifest only when curriculum and instructional demands involve information which is complex enough to challenge a student's ability to understand in the absence of conscious, effortful regulation.

So, it is too, in life when increased expectations demand the use of well - developed executive functioning in older children and adolescents, regarding intra- and interpersonal performance.

ATTENTION BASED AND LANGUAGE BASED LEARNING DISABILITIES

For persons who have attention deficit disorder, disruptions in attention are likely to set the entire system off balance. Our previous research efforts have suggested that attention dysfunction disrupts the intricate juggle among strategic processes which set the procedure for attention allocation and deeper level processing. Since this is the role of executive function, we expect, therefore, to find one manifestation of ADD at the level of executive function / extended information processing.

This network of processes, especially working memory, will also be a source of breakdown in nearly all disorders.

Both ADD's and LD's have well-documented problems with working memory .

In the ADD population it is likely that information processing problems and breakdowns in cognition will be organized directly around working memory and executive function deficits.

In contrast, information processing problems of a similar form which characterize the language based learning disabled population are likely to be organized around the linguistic module of which working memory and executive function are a part and which is driven by phonological processing.

THE LINK TO PHONOLOGICAL PROCESSING

There is a large literature concerning phonological proficiency in LD's . The dysfunction has been described as a problem which manifests primarily in working memory and its executive component. Because rapid lexical access (rapid automatic naming) is required for efficient use of total capacity and because rapid lexical access is mediated phonologically, phonological proficiency is a critical link in the attention - working memory -executive function network. Phonological processing is reflected in measures of word retrevial and can be seen in response to a word opposites task, a task of working memory for linguistically codable information, and ultimately in any task where efficient verbal mediation is required to manage complex information.

OUR CURRENT STUDY

HYPOTHESES

I.

Attention dysfunction will disrupt thinking wherever large amounts of information (academic or affective) must be managed and\or when multistep operations are required.

This disruption is mediated through breakdowns at the level of executive function. Academic areas which would be affected would include math problem solving or reading of extended passages where there is considerable information to be managed and reorganized.

II.

Breakdowns in extended processing, which requires a highly-tuned executive function, would be mediated differentially for those with attention based learning disorders vs those with language based learning disability.

II. a.

In children with ADD extended information load itself makes excessive demands on the attentional system.

II. b.

In children with learning disability we have proposed that language -related processes, particulary those which are phonologically based, are associated with breakdowns in extended processing.

III.

When attention can be controlled (by prompting or by medication) in the ADD population, issues of executive function/extended processing and working memory will no longer dominate.

We are interested in identifying the role of controlled attention, with medication or through prompting effect, on the inter-relationship among these processes.

METHODOLOGY

POPULATION CHARACTERISTICS - IN PERCENTAGES

		ADD'S (NO MEDS) n = 49	LD'S n = [illegible]50	ADD'S MEDS n = [illegible]38
SPECIAL EDUCATION:	YES	43.1	64.0	69.2
	NO	56.9	36.0	30.8
GENDER:	MALE	60.8	72.0	79.5
	FEMALE	39.2	28.0	20.5
GRADE:	1	2.0	4.0	2.6
	2	11.8	2.0	15.4
	3	19.6	6.0	23.1
	4	5.9	2.0	12.8
	5	13.7	8.0	10.3
	6	5.9	10.0	2.6
	7	9.8	18.0	10.3
	8	3.9	8.0	7.7
	9	11.8	8.0	5.1
	10	3.9	14.0	5.1
	11	3.9	10.0	
	12	7.8	10.0	5.1

Subjects were children referred to the authors' private practices.

Diagnosis of ADD was made in accordance with DSM - III and III - R criteria and medical/psychoeducational evaluation. Diagnosis of Learning Disability was made by the second author.

Subjects on medications described in this study were on a variety of pharmacologic agents which included stimulants (methylphenidate, dextroamphetamine, pemoline), and tricyclics [illegible]ine, desipramine) alone or in combination. Dosages were titrated based on emotional, behavioral, and, as much as possible in each case, cognitive responses.

TEST BATTERY

A battery of instruments was designed to evaluate:

1. **Working memory/attention:** (Detroit tests of Learning Aptitude - 2) (DTLA-2) sentence imitation (SI), word sequences (WS) and object sequences (OS). These three tasks represent working memory for linguistically codable information. SI and WS are verbal, use words, and are traditionally described as "auditory verbal", "auditory short term memory", or "auditory processing". OS uses pictures, displays them in sequence, and requires the respondent to remember the sequence, and point to the original order in a rearranged display. Despite the apparent "visual"nature of this task it requires, in fact, verbal mediation, rapid lexical access to code the stimuli and rehearse them. Both kinds of administration, through the eye and through the ear, are used to reflect different kinds of attention - executive function - working memory demands independently of misconceptions about so-called "visual" vs. "auditory" processing.

2. **Extended processing:** Gray Oral Reading Test - Revised, comprehension score (Gray CS), and Woodcock-Johnson - Revised, applied problems (WJRAP). Both of these tasks require managing a number of steps and several bits of information in order to reach an integrated understanding.

3. **Verbal Performance and Rapid Lexical Access:** DTLA-2, word opposites (WO). Woodcock-Johnson -R, passage comprehension (WJRPC).

4. **Attention Controlled Abstract Reasoning:** a comparison between the score earned for the standard administration of the Raven Standard Progressive Matrices and the score earned under a prompted condition. Prompting is described in detail in Cherkes-Julkowski & Stolzenberg (1991). Prompts consisted of focusing attention by pointing to each aspect of the stimulus pattern and instructing the child to look as the examiner pointed. The score is expressed as the Prompted Score/the Unprompted Score and is called the Raven Ratio (RavRatio).

All subjects received the same order of testing. All tests were administered individually. Groups were matched for similar prompted Raven scores. All groups had mean prompted scores from the 70th to 75th percentile.

RESULTS

FINDINGS I

Factor Structures for Processing Measures by Diagnostic Category

	Factor 1 (% variance)		Factor 2 (% variance)		Factor 3 (% variance)	
ADD no meds	**Extended Processing**		**Attention/Working Memory**		**Rapid Lexical Access**	
	RavRatio	.80	SI	.84	WJRPC	.94
	WJRAP	.79	WS	.91	WO	.59
	Gray CS	.76				
	OS	.65				
	(42.1%)		(17.6%)		(13.4%)	
LD	**Phonological Proficiency**		**Extended Processing**		**Rapid Lexical Access**	
	SI	.84	WJRAP	.81	WJRPC	.60
	WS	.91	Gray CS	.87	RavRatio	.85
	WO	.58			OS	.56
	(42.1%)		(20.6%)		(11.2%)	
ADD meds	**Language Processing**		**Phonological Proficiency**		**Reasoning Access**	
	Gray Cs	.91	WS	.90		
	WJRPC	.77	SI	.88	RavRatio	.89
	WJRAP	.65	WO	.61		
	OS	.56				
	WO	.56				
	(51.8%)		(17.2%)		(10.9%)	

Finding I. a.

The factor structures for the three populations were different.
The dynamic cognitive system interacts differentially among the three groups.

Finding I.b.

There is a factor which can be identified as extended processing in children with ADD not taking medication (ADD, no meds).
This extended processing factor accounts for the major proportion of variance among these measures in these children.

Finding I.c.

Medication treatment (ADD, meds) seems to alleviate the dominance of extended processing difficulties and to have the effect of reorganizing the factor structure into more traditional processes determining academic performance.

Finding I.d.

The LD group provides a contrast which reveals the dominance of problems with phonological proficiency which has been well documented previously.

FINDINGS II

Means & (Standard Deviations) for Measures by Diagnostic Category

	ADD's no meds	LD's	ADD's meds
WJRPC	103.21 (9.16)	107.00 (21.84)	112.43 (16.93)
WJRAP	98.42 (15.92)	104.78 (21.57)	103.43 (16.41)
GCS	8.78 (2.20)	9.35 (2.87)	10.56 (3.98)
WO	10.15 (2.67)	11.17 (3.18)	11.56 (3.01)
SI	9.84 (3.35)	10.28 (2.92)	10.75 (2.93)
WS	9.63 (2.81)	9.89 (2.93)	10.37 (2.55)
OS	10.57 (3.30)	12.50 (2.79)	9.56 (5.72)
RavRatio	2.03 (1.30)	1.46 (.34)	1.54 (.68)

Finding II. a.

Increased processing demands affect the ADD, no meds to the greatest degree (Applied Problems and Gray Comprehension).

Finding II. b.

ADD's, no meds are assisted most by refocusing attention. Their Raven Ratio (RavRatio: prompted score/unprompted score) is 2.03. ADD meds, and LDs are aided in decreasing order (ADD, meds 1.54; LD's 1.46).

Finding II. c.

Increased processing demands become a burden for ADDs, no meds & ADDs, meds when the measure simultaneously requires crossmodal transfer, stimulus reorganization, working memory and graphomotor responding (Object Sequences).

FINDINGS III

Regression of Processing Measures onto Controlled Attention

(Raven Ratio)

	Simple r	Mult R	R^2	Adjusted R^2	F(df)	P
ADDs no meds						
WJ Applied Problems	.66	.66	.44	.42	36.98 (1,47)	.000
Detroit Object Sequences	.58	.72	.52	.50	25.00 (2,46)	.000
LDs						
WJ Passage Comprehension	.44	.44	.20	.18	12.36 (1,49)	.001
ADDs meds						
WJ Applied Problems	.55	.55	.30	.28	16.49 (1,37)	.000

Finding III. a.

In both ADD groups, the medicated as well as the unmedicated, the strongest and highly significant (p.= 000) correlate of the Raven ratio is a measure of extended processing, the Woodcock-Johnson - R, Applied Problems.

Those children who are doing well with extended processing are also those whose scores are already relatively high without the benefit of re-focused attention (thus the negative simple correlations). Those who can control their attention, can also control extended processing.

Finding IIIb.

The re-focussing effect is larger for the unmedicated group and the contribution of working memory remains significant.

Finding IIIc.

The LD group is affected more by language processing measures. Lower scores on a measure of language (reading) comprehension and rapid lexical access tend to predict more benefit from controlled intake in an information processing task.

Finding IIId.

These results confirm the factor analytic findings that the dynamic cognitive system interacts differentially among these three groups.

DISCUSSION

I.

Despite the fact that children with ADD and other LDs tend to have similar processing and performance profiles, there appear to be different structures underlying these profiles. That is, though the profiles are similar, the underlying processes contributing to each group and profile are different. One is tempted to conclude, then, that individuals with ADDs will demonstrate a Learning Disability: an attention (as opposed to language) based LD. Of course, the same individual could manifest both language and attention based LD.

II.

Executive function is intricately connected with the attention network. This relationship manifests in school - related tasks requiring extended processing (math problem solving, extended reading). It is a small jump to understand how it is that the processing of complex intra- and interpersonal (social) information is so difficult for individuals with ADD.

III.

These findings uncover the direct impact of medication on the dynamic nature of information processing. Without medication, an ADD group matched for reasoning ability with a medicated group reflects a cognitive pattern dominated by two strong attentional issues: extended processing/executive function and the more traditionally acknowledged aspect of attentional functioning associated with activation and working memory.

With medication, however, an equivalent ADD group is no longer dominated by attentional processes. Processes more directly related to domain - specific issues emerge as factors. The implication is, that once attention is under control in its full complexity, including executive function and working memory, the child is ready to generate forms of processing which can flexibly respond to the specific demands of the task.

IV.

The children with LD (who are not profoundly different from the nonmedicated children with ADD in their mean performance on any one variable), are qualitatively different from ADDs, no meds in the way their processes are associated. Their performance is dominated by those processes implicated in the linguistic module: phonological processing, rapid lexical access and extended processing.

V.

Breakdowns in working memory/executive function for the LD's appear to be associated with, and directly mediated by, phonological aspects of the linguistic module. Breakdowns at the same point for ADDs are driven, not surprisingly, by attention dysfunction.

VI.

Prompting helps all groups.

Prompting interacts differentially with these two processing profiles.

In the end prompting appears to help the sequenced, controlled processing of information.

Sequencing and control can break down because: - the language necessary to code information sequentially in working memory is not available.

and / or

- attention is not modulated well enough to carve out manageable amounts of the internal and/or external stimulus field. Sequencing is a manifestation of the need to deploy attention to accomodate a limited capacity system.

VII.

These findings suggest the justification for a reconceptualization of the concept of learning disabilities to include at least two groups of children:

1) LANGUAGE BASED LDS who manifest working memory/executive function/extended processing problems which are based in the linguistic module and driven, most probably, phonologically;

2) ATTENTION BASED LDS who manifest a similar profile but whose working memory and executive function difficulties are based in attentional dysfunction.

There may be other groups as well whose profiles are similar in measured areas of dysfunction. Groups can overlap and individuals can have membership in more than one group.

VIII.

Implications for diagnosis and assessment, treatment and follow-up are profound.

The issue of age - related manifestations of attention - driven executive dysfunction is important to the identification of children with ADD and associated learning disability in school.

Despite the current DSM III -R provision that attention problems should manifest prior to age 7, these and other findings suggest that ***the developmental period crucial for attentional processes persists through adolescence neurophysiologically and attention problems may manifest anywhere along the way.*** This is so because of the continuing neurological development of the attention-working memory-executive function complex and the increasing demand on it in school and in life, with increasing age.

(Abstracts and references are available)

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